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U.S. Solar Photovoltaic Manufacturing: Industry Trends, Global Competition, Federal Support

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Summary

Every President since Richard Nixon has sought to increase U.S. energy supply diversity. Job creation and the development of a domestic renewable energy manufacturing base have joined national security and environmental concerns as reasons for promoting the manufacturing of solar power equipment in the United States. The federal government maintains a variety of tax credits and targeted research and development programs to encourage the solar manufacturing sector, and state-level mandates that utilities obtain specified percentages of their electricity from renewable sources have bolstered demand for large solar projects.

The most widely used solar technology involves photovoltaic (PV) solar modules, which draw on semiconducting materials to convert sunlight into electricity. By year-end 2013, the total number of grid-connected PV systems nationwide reached more than 445,000. Domestic demand is met both by imports and by about 75 U.S. manufacturing facilities employing upwards of 30,000 U.S. workers in 2014. Production is clustered in a few states including California, Ohio, Oregon, Texas, and Washington.

Domestic PV manufacturers operate in a dynamic, volatile, and highly competitive global market now dominated by Chinese and Taiwanese companies. China alone accounted for nearly 70% of total solar module production in 2013. Some PV manufacturers have expanded their operations beyond China to places like Malaysia, the Philippines, and Mexico. Overcapacity has led to a precipitous decline in module prices, which have fallen 65%-70% since 2009, causing significant hardship for many American manufacturers. Some PV manufacturers have closed their U.S. operations, some have entered bankruptcy, and others are reassessing their business models. Although hundreds of small companies are engaged in PV-related manufacturing around the world, profitability concerns appear to be driving consolidation, with fewer than a dozen firms now controlling half of global module production.

In 2012, the United States imposed significant dumping and countervailing duties on imports of Chinese solar products after ruling that U.S. producers had been injured by dumped and subsidized solar equipment from China. In a second case, the U.S. Department of Commerce (DOC) and the U.S. International Trade Commission (ITC) ruled in 2014 and early 2015 that U.S. producers were being injured by imports of Chinese-made modules that avoided the duties imposed in 2012 by incorporating solar cells from Taiwan. While these duties may help U.S. production become more competitive with imports, the cost of installing solar systems might rise. Domestic demand for solar products may also be depressed by the end of various federal incentives. Unless extended, the commercial Investment Tax Credit for PV systems will revert to 10% from its current 30% rate after 2016, while the 30% credit for residential investments will expire.

Looking ahead, the competitiveness of solar PV as a source of electric generation in the United States will likely be adversely affected by the rapid development of shale gas, which has lowered the cost of gas-fired power generation and made it harder for solar to compete as an energy source for utilities. In light of these developments, the ability to sustain a significant U.S. production base for PV equipment is in question.

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Introduction

Major developments affecting the domestic photovoltaic (PV) manufacturing sector include technological advances, improved production methods, dramatically lower prices for PV modules, and trade frictions, particularly with China.[1] These volatile industry trends have adversely affected the operations of many solar companies, forcing some to reassess their business models and others to close factories or declare bankruptcy.[2] In addition, the rapid growth in shale gas production has the potential to affect the competitiveness of solar power, as cheap natural gas possibly may provide an alternative source of energy at a lower price. If oil and gas prices stay low, demand for renewable energy, including solar, might be hurt. These trends affect the ability of the United States to build a sustained domestic production base for PV equipment.

U.S. solar manufacturing makes up a small part of the U.S. manufacturing base. In 2014, the nation's solar manufacturing industry directly employed about 32,000 workers, according to the Solar Energy Industries Association (SEIA), a trade group.[3] The U.S. cell and module market, measured by domestic shipment revenues, has grown in size from $3.3 billion in 2008 to $7.1 billion in 2012, reports the U.S. Energy Information Administration (EIA).[4] Following an unprecedented period of growth, the number of PV systems in the United States reached more than 445,000 by the end of 2013, more than twice the total at the end of 2011.[5]

Government support has been instrumental in sustaining the solar industry worldwide. In the United States, tax incentives and stimulus funding have helped to spur new PV installations. In its 2013 annual report, SEIA wrote that "more solar has been installed in the United States in the last eighteen months than in the 30 years prior."[6] Nevertheless, even with direct government

A PV Glossary

PV stands for photovoltaic, a term derived from "photo" for light and "voltaic" for a volt, a unit of electrical force.

Solar photovoltaic, or solar PV, is a technology that uses the basic properties of semiconductor materials to transform solar energy into electrical power.

A *solar PV cell* is an electricity-producing device made of semiconducting materials. Cells come in many sizes and shapes. Materials used to make cells include monocrystalline silicon, polycrystalline silicon, amorphous silicon (a-Si), cadmium telluride (CdTe), copper indium gallium (di)selenide (CIGS), and copper indium (di)selenide (CuInSe2 or CIS).

Panels, or *modules,* are assembled from a number of solar cells.

An array is the collective name for a number of *solar modules* connected together.

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[1] Ehren Goossens, "Solar Boom Driving First Global Panel Shortage Since 2006," *Bloomberg*, August 19, 2014, http://www.bloomberg.com/news/2014-08-18/solar-boom-driving-first-global-panel-shortage-since-2006.html.

[2] Industry observers reported in 2014 average module and cell prices fell 11% and 16%, respectively. See David Feldman, Robert Margolis, and Daniel Boff, *Q3/Q4 '14 Solar Industry Update*, January 20, 2015, p. 32.

[3] Solar Foundation, *National Solar Jobs Census 2014*, The Annual Review of the U.S. Solar Workforce, January 2015, p. 6. Its count reflects solar jobs as of November 2014. By comparison, there were more than 12 million jobs in overall U.S. manufacturing in 2014.

[4] U.S. Energy Information Administration (EIA), *Solar Photovoltaic Cell/Module Shipments Report*, 2012, December 2013, Table 2, p. 8, http://www.eia.gov/renewable/annual/solar_photo/. Shipments data for 2008 are from Table 3.6 of EIA's 2008 annual PV module/cell manufacturing survey, http://www.eia.gov/renewable/annual/solar_photo/archive/solarpv08.pdf.

[5] SEIA reported cumulative PV installations of more than 214,000 in 2011. SEIA, *2011 Year-in-Review Executive Summary*, March 2012, p. 30, and *U.S. Solar Market Insight Report*, 2013 Year-in-Review Full Report, March 4, 2014, pp. 57-58.

[6] SEIA, *U.S. Solar Market Insight Report, 2013 Year-In-Review*, 2013, p. 7.

involvement, solar energy merely accounts for 0.5% of overall U.S. electricity generation.[7] The Obama Administration actively supports greater deployment of solar energy and sees it as one way to encourage advanced manufacturing in the United States, create skilled manufacturing jobs, and increase the role of renewable energy technology in energy production, among other objectives. In its *Solar Progress Report: Advancing Toward a Clean Energy Future*, the Obama Administration argues that "The Administration's investments have helped expand U.S. manufacturing capabilities, including new facilities to produce cost-effective, high quality solar panels as well as startup operations to commercialize novel PV and concentrating solar power (CSP) technologies."[8]

This report looks at the solar photovoltaic manufacturing industry and its supply chain; employment trends; international trade flows; and federal policy efforts aimed at supporting the industry. It does not cover other methods of solar-power generation, such as concentrating solar power plants.[9] Concentrating solar technologies, largely dormant prior to 2006, are suitable mainly for utility-scale generation, whereas solar photovoltaics can be arranged in small-scale installations to produce power for individual buildings and in large installations to supply power to utilities.

Even with decreasing PV prices, producing equipment that generates solar power at prices competitive with electricity generated from fossil fuels remains a challenge.[10] This is particularly true for utility-scale installations, as wholesale purchasers of electricity will compare the cost per megawatt hour of solar power directly with the cost of power from other sources. The cost-competitiveness of solar power is better in the residential and business markets, as the relevant comparison is with the delivered cost of electricity rather than with the generating cost. But even if the popularity of solar systems grows, falling equipment prices are likely to undermine efforts to sustain a solar manufacturing base in the United States.

Solar Photovoltaic (PV) Manufacturing

Solar PV manufacturing, previously undertaken by numerous small firms, is rapidly maturing into a global industry dominated by a smaller number of producers. Cell manufacturers typically have proprietary designs that seek to convert sunlight into electricity at the lowest total cost per

[7] The U.S. Department of Energy (DOE) reported that annual installed solar PV capacity grew at a compound annual growth rate of 64% between 2000 and 2013, but provided .5% of total electricity generation in 2013. By comparison, U.S. wind installations grew at a compound annual growth rate of 26% from 2000 to 2013 and represented 4.1% of total electricity generation in 2013. See pp. 24 and 27 of the U.S. Department of Energy's *2013 Renewable Energy Data Book*, January 20, 2015, http://www.nrel.gov/docs/fy15osti/62580.pdf.

[8] The White House, *Solar Progress Report: Advancing Toward a Clean Energy Future*, May 2014, p. 4.

[9] Two principal technologies—parabolic troughs and solar towers—are used in concentrated solar power installations that employ large arrays of mirrors to focus energy on a single point and result in tremendous amounts of heat, creating steam to turn turbines. CSP projects, which involve manufacturers such as Abengoa, AREVA, Brightsource Energy, Solar Reserve, Schott Solar, and Toresol are large-scale and require high initial investment; thus mainly utilities or large tower producers use this technology. In 2013, 885 MW of CSP was added worldwide, in contrast to the installation of 39 GW of solar PV. Concentrating Photovoltaic (CPV) technology, which has been around since the 1970s, uses optics such as lenses to concentrate a large amount of sunlight onto a small area of solar photovoltaic materials to generate electricity. According to the European Union's 2013 *PV Status Report*, about 60 companies are developing new products for the CPV market, with the majority located either in the United States or Europe. Various analysts forecast that the CPV market could reach 500 MW by 2015 and 1 GW by 2020. The report can be found at http://iet.jrc.ec.europa.eu/remea/pv-status-report-2013.

[10] The average price of PV modules fell to $1.15 per watt in 2012 from $1.59 per watt in 2011, a drop of 38%, according to EIA.

kilowatt hour. Vertical integration, whereby manufacturers produce their own components from wafers to modules, is becoming more common, but many PV manufacturers still rely on extensive supply chains for components such as wafers, glass, wires, and racks. Worldwide, the market for solar PV (including modules, system components, and installations) expanded from $2.5 billion in 2000 to $91.3 billion in 2013, according to one estimate.[11]

The Manufacturing Process

PV systems do not require complex machinery and thousands of parts. In fact, most PV systems have no moving parts at all. They also have long service lifetimes, typically ranging from 10 to 30 years, with some minor performance degradation over time. In addition, PV systems are modular; to build a system to generate large amounts of power, the manufacturer essentially joins together more components than required for a smaller system. These characteristics make PV manufacturing quite different from production of most other types of generating equipment. In particular, PV systems offer little opportunity for manufacturers to make customized, higher-value products to meet unique needs. Manufacturers offer competing technological approaches to turning sunlight into electricity, but many customers have no reason to care about the technology so long as the system generates the promised amount of electricity. Economies of scale are significant, as increasing output tends to lower a factory's unit costs.

Crystalline silicon PV is the main technology used by solar manufacturers, and accounted for about 90% of global PV production in 2013.[12] Production of a crystalline silicon system involves several stages:

- **Polysilicon Manufacturing.** Polysilicon, based on sand, is the feedstock for the PV and semiconductor industries. It is the material used to make the semiconductors that convert sunlight into electricity. Polysilicon accounts for about a quarter of the cost of a finished solar panel.[13] Approximately 90% of demand for polysilicon comes from the solar PV industry.[14] Production requires large processing plants that may cost of up to $1 billion to build.[15] Historically, polysilicon prices have been volatile because the construction of a new plant can add a large amount of supply to the market. A handful of manufacturers dominate polysilicon production. In 2013, the largest polysilicon manufacturer was GLC Poly from China, followed by Wacker-Chemie from Germany, Hemlock from the United States, and OCI from South Korea. In 2013, nearly half of the world's polysilicon was produced by Chinese and South Korean companies.[16]

[11] Ron Pernick, Clint Wilder, and James Belcher, *Clean Energy Trends 2014*, CleanEdge, March 2014, p. 4.

[12] Arnulf Jager-Waldau, *PV Status Report 2013*, European Commission, DG Joint Research Centre, September 2013, pp. 35-36.

[13] Alim Bayaliyev, Julia Kalloz, and Matt Robinson, *China's Solar Policy,* George Washington University, Subsidies, Manufacturing Overcapacity & Opportunities, December 23, 2011, p. 16, http://citeseerx.ist.psu.edu/viewdoc/download?rep=rep1&type=pdf&doi=10.1.1.226.1981. The semiconductor industry also uses polysilicon, but increasingly demand for it has shifted to solar PV products.

[14] "Bernreuter Research: Ramp-Up Delays to Stabilize Polysilicon Price, Market Research Firm Predicts Short-Term Increased Followed by Downtrend," *SolarServer*, July 10, 2014, http://www.solarserver.com/solar-magazine/solar-news/current/2014/kw28/bernreuter-research-ramp-up-delays-to-stabilize-polysilicon-price-market-research-firm-predicts-short-term-increase-followed-by-downtrend.html.

[15] Green Rhino Energy, *Value Chain Activity: Producing Polysilicon*, http://www.greenrhinoenergy.com/solar/industry/ind_01_silicon.php.

[16] Bloomberg New Energy Finance, "PV Production 2013: An All-Asian Affair," Solar Insight—Research Note, April

- **Wafer Manufacturing.** Using traditional semiconductor manufacturing equipment, wafer manufacturers, including companies such as Elkem, LDK Solar, Okmetic, Siltronic, Nexolon, and SunEdison (formerly MEMC), shape polysilicon into ingots and then slice the ingots into thin wafers.[17] The wafers are then cut, cleaned, and coated according to the specifications of the system manufacturers.
- **Cell Manufacturing.** Solar cells are the basic building blocks of a PV system. They are made by cutting wafers into desired dimensions (typically 5 x 5 or 6 x 6 inches) and shapes (round, square, or long and narrow). The manufacturer, such as Yingli, Trina Solar, or Sharp, then attaches copper leads so the cell can be linked to other cells. Minimizing the area covered by these leads is a key issue in cell design, as the lead blocks sunlight from reaching parts of the cell surface and thus reduces potential energy output. The U.S. Department of Energy (DOE) estimated in 2011 that a manufacturing plant to produce 120 megawatts (MW) of cells per year would require an investment of around $40 million.[18]
- **Module Manufacturing.** Modules, which normally weigh 34 to 62 pounds, are created by mounting 60 to 72 cells on a plastic backing within a frame, usually made of aluminum.[19] Chinese manufacturers have come to dominate module manufacturing,[20] making up about 70% of the total global production in 2013.[21] The module is covered by a special solar glass, which protects the unit against the elements and maximizes the efficiency of the unit that coverts sunlight into power. Production of solar glass is highly capital intensive, and approximately 60% of the global market is controlled by four manufacturers: Ashai, NSG Group (Pilkington), Saint Gobain, and Guardian.[22] The glass is expensive to ship, so glass producers tend to locate near module manufacturers.[23] In some countries, module manufacturing is highly automated; in others, more labor-intensive processes are used.

16, 2014, pp. 2-4, http://about.bnef.com/content/uploads/sites/4/2014/04/2014-04-16-PV-production-2013-an-all-Asian-affair.pdf.

[17] "Top Silicon Wafer Manufacturing Companies in the World," *Electronics and You*, June 14, 2013, http://www.electronicsandyou.com/blog/top-silicon-wafer-manufacturing-companies-in-the-world.html.

[18] U.S. Department of Energy, Energy Efficiency & Renewable Energy, *Solar Photovoltaic Economic Development*, Building and Growing a Local PV Industry, November 2011, p. 53.

[19] IEA-PVPS, *Trends 2014 in Photovoltaic Applications*, Survey Report of Selected IEA Countries between 1992 and 2013, October 12, 2014, p. 6.

[20] According to SolarBuzz, China's Yingli Green, Trina Solar, and Canadian Solar were the largest manufacturers of modules by megawatts shipped in 2013. The U.S. manufacturer First Solar dropped to seventh in the world in 2013 from second place in 2012. Other rankings may differ according to what is counted and when.

[21] Bloomberg New Energy Finance, "PV Production 2013: An All-Asian Affair," Solar Insight—Research Note, April 16, 2014, pp. 5-7, http://about.bnef.com/content/uploads/sites/4/2014/04/2014-04-16-PV-production-2013-an-all-Asian-affair.pdf.

[22] Green Rhino Energy, Value Chain Activity: Manufacturing Solar Glass, http://www.greenrhinoenergy.com/solar/industry/ind_15_solarglass.php.

[23] AGC Solar is owned by Asahi Glass of Japan. Citing weak demand, in 2012 it closed its solar glass factory in Kingsport, TN, where it had produced solar glass for the U.S. market. AGC Solar, "ACG Decides to Close PV Cover Glass Production Base in the United States," press release, August 11, 2012, http://www.agc-solar.com/en/news-events/news/article/agc-decides-to-close-pv-cover-glass-production-base-in-the-united-states-133.html.

A newer technology, thin-film PV, accounts for about 20% of total solar PV production.[24] Rather than using polysilicon, these cells use thin layers of semiconductor materials like amorphous silicon (a-Si), copper indium diselenide (CIS), copper indium gallium diselenide (CIGS), or cadmium telluride (CdTe). The manufacturing methods are similar to those used in producing flat panel displays for computer monitors, mobile phones, and televisions: a thin photoactive film is deposited on a substrate, which can be either glass or a transparent film. Afterwards, the film is structured into cells. Unlike crystalline modules, thin-film modules are manufactured in a single step. Thin-film systems are usually less costly to produce than crystalline silicon systems, but have substantially lower efficiency rates.[25] On average, thin-film cells convert 5%-13% of incoming sunlight into electricity, compared to 12%-21% for crystalline silicon modules.[26] Looking ahead, relatively newer thin-film technology may offer greater opportunities for technological improvement.[27] In the United States, First Solar is the largest thin-film panel manufacturer, with an annual production capacity of 280 MW.[28]

Crystalline silicon systems and thin-film systems all make use of a variety of other components, known as "balance of system" equipment. These include batteries (used to store solar energy for use when the sun is not shining), charge controllers, circuit breakers, meters, switch gear, mounting hardware, power-conditioning equipment, and wiring. In the United States, inverters are also needed to convert the electricity generated from direct current (DC) to alternating current (AC) electricity compatible with the electric grid. Usually, balance of system components are not made by the system manufacturers, but are sourced from external suppliers.

Similar to many other advanced manufacturing industries, solar panel manufacturing depends on a global supply chain (see **Figure 1**), with PV manufacturers sourcing products at each stage of the value chain from suppliers located anywhere in the world. For instance, PV manufacturers purchase the majority of their solar factory equipment for wafer, cell, and module production from European and U.S. firms such as Roth & Rau (Germany), Applied Materials (United States), GT Solar (United States), and Oerlikon Solar (Switzerland). As an example, a system produced by the U.S. firm SunPower may include wafers from its AUO joint venture partner in Malaysia, cells manufactured at its factory in the Philippines, and modules from its assembly facilities in Mexico or France.[29]

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[24]Arnulf Jager-Waldau, *PV Status Report 2013*, European Commission, DG Joint Research Centre, September 2013, p. 36.

[25] Efficiency, which measures the percentage of the sun's energy striking the cell or module, is one important characteristic of a solar cell or module. Over time, average cell efficiencies have increased. Jochen Siemer and Beate Knoll, "Still More than Enough," *Photon International*, February 2013, pp. 72-73.

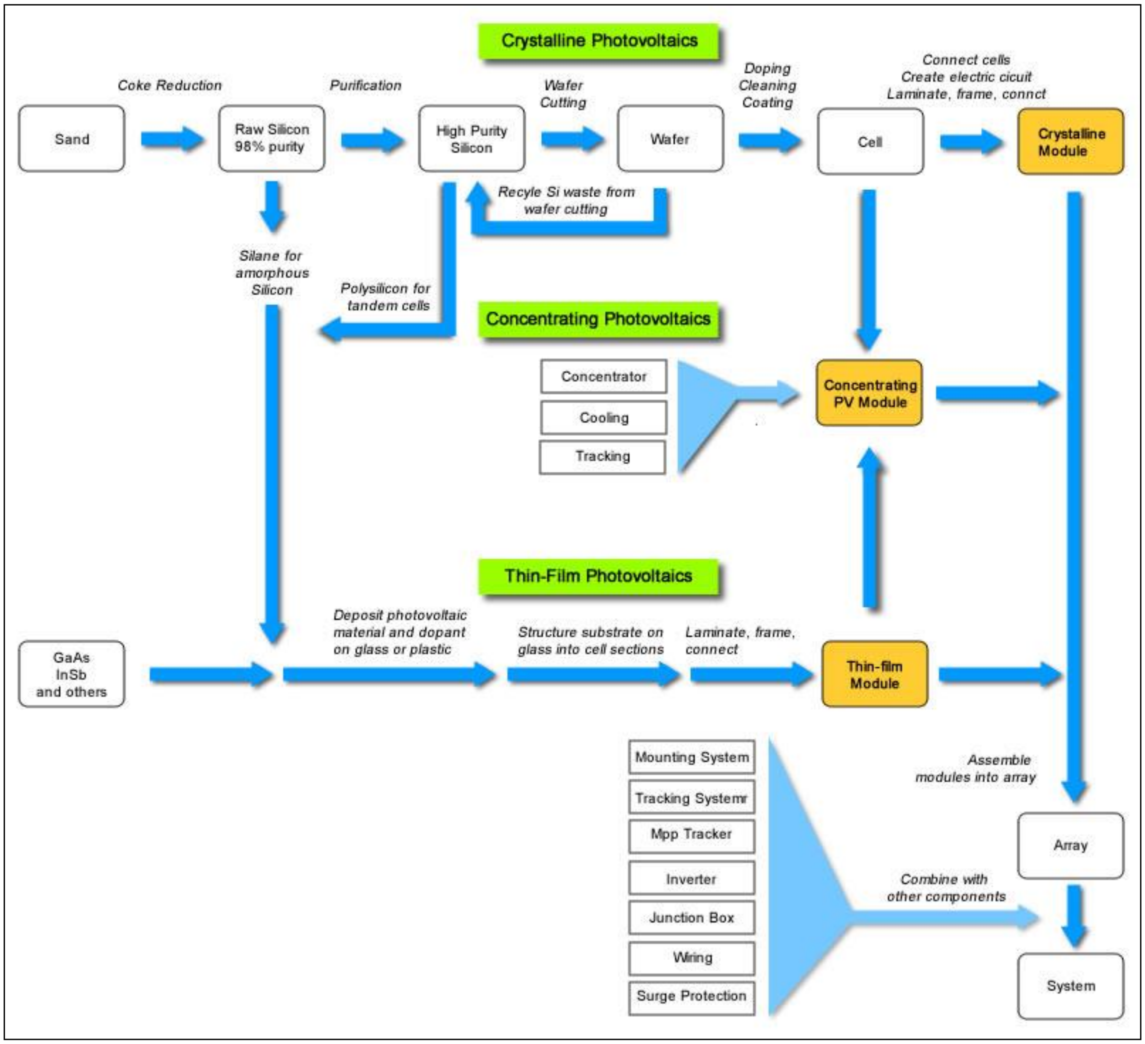
[26] Arnulf Jager-Waldau, *PV Status Report 2013*, p. 35.

[27] In recent years, some thin-film module manufacturers have announced Chapter 11 bankruptcy, including Abound Solar, Beacon Power, Solyndra, and Energy Conversion Devices, which owns United Solar Ovonic. In 2013, Hanergy, a Chinese manufacturer, bought MiaSole, another struggling U.S. manufacturer.

[28] David Feldman and Robert Margolis, *National Survey Report of PV Power Applications in the United States 2012*, IEA-PVPS, November 4, 2013, pp. 14-15.

[29] SunPower, Form 10-K Annual Report, February 18, 2014, p. 43, investors.sunpower.com/.

Figure 1. PV Value Chain



Source: Green Rhino Energy, http://www.greenrhinoenergy.com/solar/technologies/pv_valuechain.php. Reproduced with permission from Green Rhino Energy.

Each solar panel assembler uses different sourcing strategies, and the levels of vertical integration vary across the industry. At one extreme, SolarWorld, based in Germany, is highly integrated, controlling every stage from the raw material silicon to delivery of a utility-scale solar power plant. At the other extreme, some large manufacturers are pure-play cell companies, purchasing polysilicon wafers from outside vendors and selling most or all of their production to module assemblers. A number of solar manufacturers seem to be moving toward greater vertical integration for better control of the entire manufacturing process. Vertical integration also reduces the risk of bottlenecks holding up delivery of the final product.

Labor costs account for less than 10% of production costs for U.S. solar cell and module producers.[30] According to Suntech, a Chinese module manufacturer, labor makes up 3%-4% of

[30] USITC, *Crystalline Silicon Photovoltaic Cells and Modules from China*, Publication 4360, November 2012, Table VI-2, p. VI-4.

the cost of making crystalline solar panels.[31] A 2011 study by the U.S. International Trade Commission (ITC) reported that even the more labor-intensive module assembly process is being automated, and that module assembly in China and the United States uses similar levels of automation.[32] International transport costs for finished modules are also small, in the range of 1%-3% of value, producers have told the ITC.[33]

Production and transportation costs do not appear to be the major considerations in determining where manufacturing facilities are located. In 2011, according to a National Renewable Energy Laboratory presentation, Chinese producers had an inherent cost advantage of no greater than 1% compared with U.S. producers; in the U.S. market, China suffered a 5% cost disadvantage before the imposition of antidumping and countervailing duties in 2012 and 2015.[34]

Production Locations

With neither labor costs nor transportation costs being decisive, many manufacturers that opened new facilities over the past decade chose to locate them in countries with strong demand—which generally have been countries with attractive incentives for PV installations. Worldwide, the biggest markets have been Europe (principally Germany, Italy, and Spain) and Japan. Together, they comprised about two-thirds of the world's PV installed capacity of nearly 139 GW in 2013.[35] Since 2011, a number of European governments have reduced solar incentives such as feed-in tariffs (FITs), which require utilities to purchase renewable power at generous rates. These policy changes contributed to lower demand for solar PV installations in Europe, adversely affecting European solar manufacturing.[36] In Germany, for example, the market decreased significantly. In 2013, 40 companies manufactured 1,230 MW of PV cells and modules, compared with 62 PV companies with production of about 2,700 MW in 2008.[37] The Japanese government has sustained its domestic solar PV market by offering various inducements, which include a feed-in tariff, tax incentives, and direct grants for solar PV.[38] South Korea, China, Malaysia, and the Philippines also provide various types of support to their domestic solar manufacturing sectors.

The U.S. market for PV products has grown in recent years, accounting for about 12% of global PV installations in 2013 (see **Figure 2**).[39] One reason for the increase was the development of leasing and financing options that lower up-front costs to households and businesses. SEIA

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[31] Nathaniel Ahrens, *China's Competitiveness: Myth, Reality, and Lessons for the United States*, Center for Strategic & International Studies (CSIS), Case Study: Suntech, January 2013, p. 17, http://csis.org/program/chinas-competitiveness.

[32] USITC, *Crystalline Silicon Photovoltaic Cells and Modules from China*, Publication 4295, December 2011, p. 40.

[33] Ibid, pp. V-4.

[34] Alan Goodrich, Ted James, and Michael Woodhouse, *Solar PV Manufacturing Cost Analysis: U.S. Competitiveness in a Global Industry*, National Renewable Energy Laboratory, October 10, 2011, p. 26, http://www.nrel.gov/docs/fy12osti/53938.pdf.

[35] European Photovoltaic Industry Association (EPIA), *Global Market Outlook for Photovoltaics, 2014-2018*, July 22, 2014, p. 17, http://www.epia.org/news/publications/global-market-outlook-for-photovoltaics-2014-2018/.

[36] REN21, *Renewables 2014 Global Status Report*, 2014, p. 111, http://www.ren21.net/portals/0/documents/resources/gsr/2014/gsr2014_full%20report_low%20res.pdf.

[37] IEA-PVPS, *National Survey Report of PV Power Applications in Germany*, 2013, p. 20, and *National Survey Report of PV Power Applications in Germany*, 2008, May 2009, p. 18.

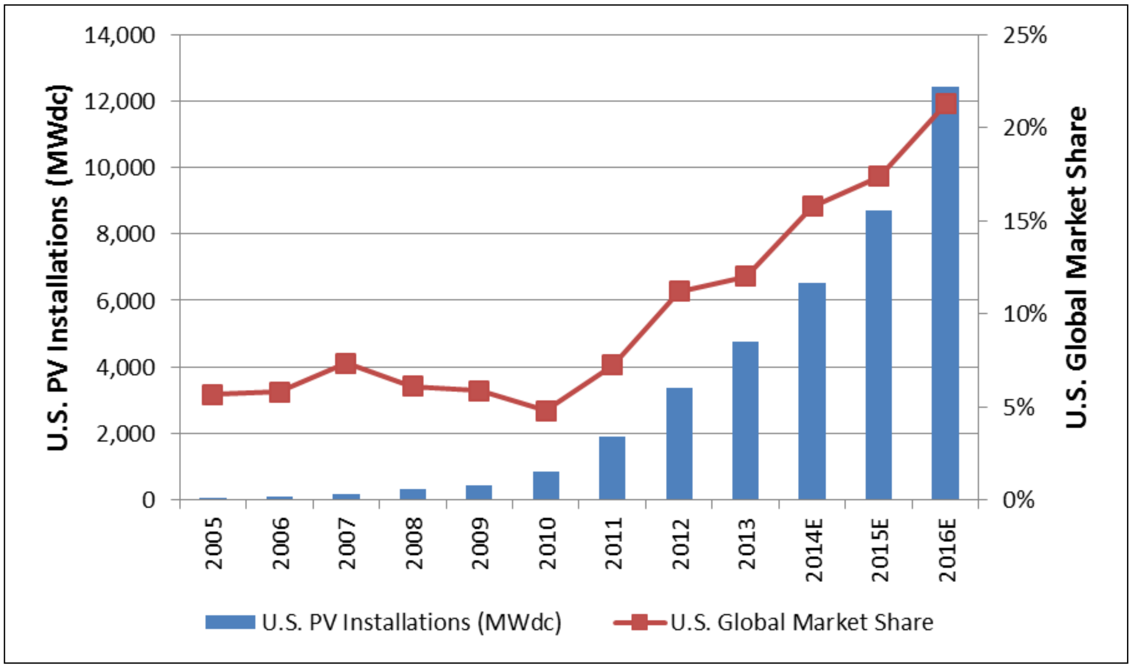
[38] Unlike some European countries, Japan continues to support renewable energy. On July 1, 2012, its Renewable Energy Law came into force, which introduced FITs for solar, wind, biomass, geothermal and small hydro.

[39] EPIA, *Global Market Outlook for Photovoltaics, 2014-2018*, July 22, 2014, p. 9. http://www.epia.org/news/publications/global-market-outlook-for-photovoltaics-2014-2018/.

reports cumulative PV capacity in the United States reached almost 5 GW at year-end 2013. Of new installations linked to the electric grid during 2013,

- 23% were for commercial or other non-residential customers, excluding utilities;
- 60% consisted of utility-scale installations, which generally use the largest panels and provide electricity directly to the electric grid; and
- 17%, the smallest share, were for residential buildings.[40]

Figure 2. U.S. PV Installations and Global Market Share



Source: SEIA/GTM Research, "U.S. Solar Market Insight Report: 2013 Year-in-Review", and EPIA "Global Market Outlook for Photovoltaics, 2014-2018."

Notes: The annual installed figures cover only grid-connected capacity. DC stands for direct current, the type of power output by photovoltaic cells and modules.

Domestic Production

In the United States, manufacturers produced PV modules with a capacity of 715,000 peak kilowatts[41] (kW) in 2012. By value, combined U.S. PV cell and module shipments totaled about $7 billion in 2012.[42] As shown in **Table 1**, SolarWorld and First Solar accounted about half of total domestic module production.

[40] SEIA, *U.S. Solar Market Insight Report*, 2013 Year-in-Review Full Report, 2014, pp. 9-24.

[41] Peak gigawatts indicate the amount of power a photovoltaic cell or module will produce at standard test conditions (normally 1 billion watts per square meter and 25 degrees Celsius).

[42] Value includes charges for cooperative advertising and warranties, but does not include excise taxes and the cost of freight or transportation. EIA, *Solar Photovoltaic Cell/Module Shipments Report 2012*, December 2013, Table 2, p. 8, http://www.eia.gov/renewable/annual/solar_photo/. In 2012, cell shipments totaled nearly $1.7 billion, and module shipments reached $5.3 billion.

Table 1. Cell and Module Production in the United States
(in MW, 2012)

Company	Location of Headquarters	Technology	Cells	Modules	% of U.S. Module Production
SolarWorld	Germany	Mono/Multi c-Si	412	243	25.6%
First Solar	United States	CdTe		229	24.1%
Sharp	Japan	Mono/Multi c-Si		116	12.2%
Suniva	United States	Mono/Multi c-Si	102	63	6.6%
SunPower	United States	Mono/Multi c-Si		61	6.4%
All Others			8	237	25.0%
Total			**522**	**949**	**100.0%**

Source: International Energy Agency, U.S. PV Applications National Survey Report (IEA-PVPS), 2012, November 2013, pp. 14-16. The 2013 U.S. national report does not give company-specific information for cell and module production.

Notes: C-Si stands for crystalline silicon. Monocrystalline PV cells are usually cut from a single grown silicon ingot, while multicrystalline PV cells are manufactured such that wafers are made from multiple crystals. Monocrystalline PV cells have an efficiency of 16% to almost 20%, while the cheaper to produce multicrystalline PV cells achieve an efficiency of 14% to 15%. Thin-film PV is based on other materials such as amorphous silicon (a-Si), cadmium telluride (cdTe), or copper iridium diselenide (CIGS).

SEIA reports the U.S. solar manufacturing sector in 2014 was made up of about 75 production sites that manufacture primary PV components (polysilicon, wafers, cells, modules, and inverters) and more than 450 additional domestic facilities that manufacture other PV-related products such as racking hardware and manufacturing equipment.[43] SolarWorld's Oregon facility is the largest solar cell and module plant in the United States, with the capacity to produce 500 MW of solar cells per year at full production. Other foreign-based firms, such as Sanyo Solar and SMA Solar, also operate PV primary component plants in the United States.

As shown in **Figure 3**, manufacturing facilities for primary solar PV equipment and components are located throughout the United States, with concentrations in California, Oregon, Ohio, Texas, and Washington. Due to the global supply chains prevalent in the PV industry, the amount of domestic content may vary considerably from one plant to another. The map does not include announced facilities that have yet to start operating.

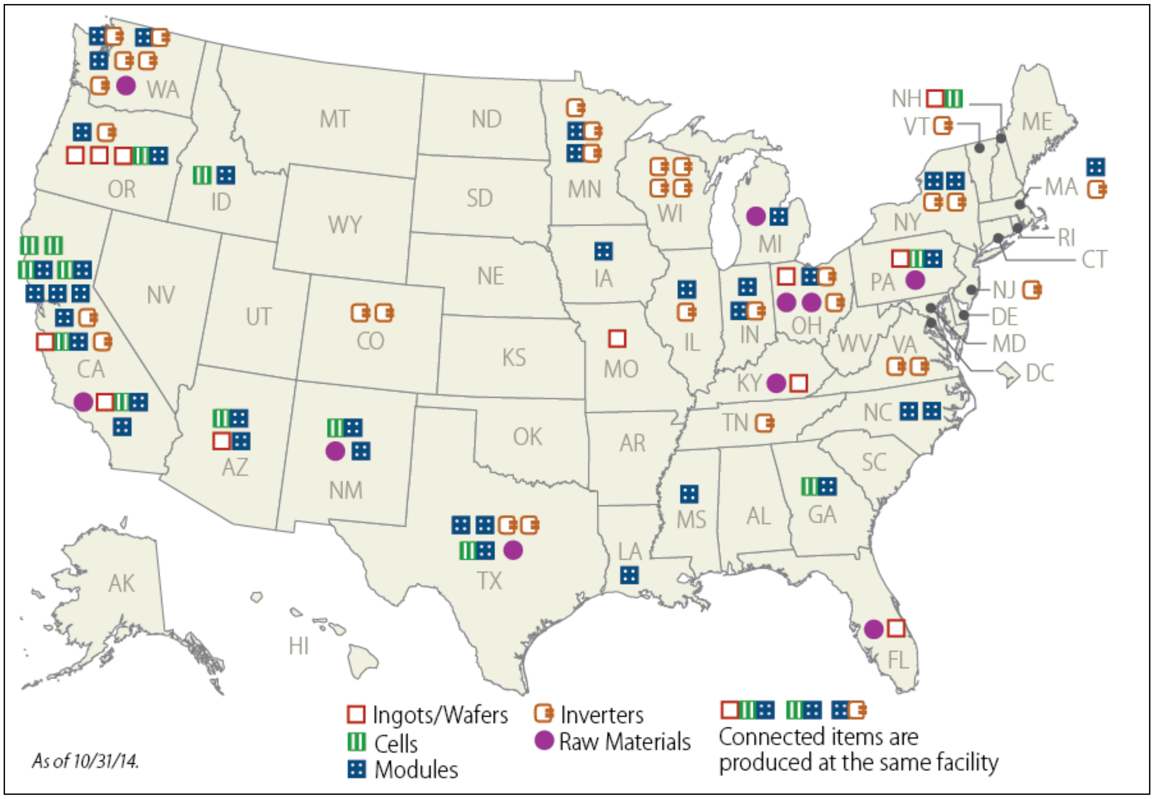
A closer look at SEIA's data shows that in 2014, roughly two dozen U.S. facilities either produced raw materials for the PV industry or were involved in wafer/ingot production. About another 50 facilities made cells or assembled modules, and some 30 were involved in the production of solar inverters.[44] SEIA's list does not include other parts of the PV supply chain, such as equipment for the PV industry or other balance of system components.

[43] SEIA data provided to CRS from its National Solar Database, November 2014.

[44] Totals by production line do not add to the number of individual PV manufacturing sites because some sites produce more than one product line.

Figure 3. U.S. Cell/Module and Polysilicon Production Facilities

(2014)



Source: SEIA, October 31, 2014.

Notes: This map is not inclusive of all PV facilities in the United States.

Challenging market conditions have led to numerous bankruptcies and manufacturing consolidations among solar firms. Consequently, several manufacturers have recently reduced, idled, or closed their U.S. operations, including Suntech,[45] Kyocera, and Schott Solar. Other manufacturers such as Hemlock Semiconductor[46] and GE Energy have abandoned their plans to build new solar factories in the United States.[47] Generally, PV production facilities appear to have relatively short life spans, at least in the United States.[48] A large share of the facilities that have closed operated for less than five years (see **Table 2**).

[45] Suntech, the only Chinese module manufacturer with a production plant in the United States and the world's largest cell and module manufacturer in 2011, filed for bankruptcy in 2014. Wuxi Suntech acquired by Shunfeng Photovoltaic has more than 2,000 MW of annual production capacity in China.

[46] Hemlock Semiconductor, "Hemlock Semiconductor Group Closes Tennessee Manufacturing Facility as a Result of Industry Oversupply, International Trade Disputes," press release, December 17, 2014, http://www.hscpoly.com/content/hsc_comp/hsc-tennessee-manufacutring-facility-closure.aspx.

[47] Mark Jaffee, "GE Abandons Plans for Aurora Solar Plant; 50 Jobs Lost at Arvada Lab," *Denver Post,* August 6, 2013.

[48] According to a Bloomberg New Energy Finance analyst, new PV manufacturing plants become obsolete within five years. "Sunset for Suntech," *Economist*, March 30, 2013.

Table 2. Selected Recent PV Facility Closures

Company	Status	Year Online	Year Closed	State	Products
Abound Solar	Closed	2009	2012	CO	Module
Evergreen Solar Inc.	Closed	2008	2011	MA	Wafers
Helios USA	Closed	2010	2013	WI	Modules
MEMC Southwest Inc.	Closed	1995	2011	TX	Ingots
Nanosolar	Closed	2009	2013	CA	Modules
MX Solar[a]	Closed	2010	2012	NJ	Modules
SolarWorld Americas[b]	Closed	2007	2011	CA	Modules
Solon America Corp.	Closed	2008	2011	AZ	Modules
Solar Power Industries	Closed	2003	2011	PA	Cells, modules
Solyndra Inc.	Closed	2010	2011	CA	Modules
SpectraWatt Inc.[c]	Closed	2009	2011	NY	Cells
BP Solar[d]	Closed	1998	2012	MD	Cells, modules
Energy Conversion Devices	Closed	2003	2011	MI	Cells, modules
Suntech	Closed	2010	2013	AZ	Modules
Sharp Solar[e]	Closed	2003	2014	TN	Modules
Sanyo	Closed one factory	2003	2012	CA	Wafers

Source: SEIA. Annual Market Reports, 2010, 2011, 2012, and 2013.

a. Helios USA and MX Solar were two of the seven petitioners in the 2011-2012 solar trade case against China.

b. SolarWorld purchased the California facility from Royal Dutch Shell in 2006 and expanded it with a $30 million investment. It remains open for sales and marketing activities, but production was moved to Oregon.

c. SpectraWatt was a 2008 spinoff from an internal research project by the Intel Corporation. The company began shipments from its New York facility in 2010.

d. Plant originally owned by Solarex, which opened it in 1981. In 1995, Amoco/Enron acquired Solarex and subsequently BP acquired it. In 2005, BP announced plans to double the plant's capacity.

e. Sharp Solar ended production in Memphis, TN, in March 2014 to focus on its domestic Japanese market.

A considerably smaller number of manufacturers have opened or announced plans to open new U.S. manufacturing plants or expand existing ones.[49] 1366 Technologies in Massachusetts[50] and Mission Solar in Texas[51] are among the solar factories that have opened since 2012. Stion, a CIGS thin-film manufacturer in Mississippi, announced that it expects to increase its solar panel

[49] SEIA, using information from press reports, says that eight PV manufacturing facilities were added in 2012, four in 2013, and two in 2014. These figures do not include manufacturers that may have gone out of business in previous years.

[50] 1366 Technologies, "1366 Technologies Celebrates Opening of New Manufacturing Facility," press release, January 30, 2013, http://1366tech.com/1366-technologies-celebrates-opening-of-new-manufacturing-facility/.

[51] Mission Solar is a joint venture between OCI Solar Power and Nexolon of South Korea. "Mission Solar Opens Doors in Texas," *Recharge*, September 22, 2014.

manufacturing capacity in 2015.[52] In 2014, Suniva began construction of a second solar PV facility in Michigan.[53]

Because of the widespread use of global supply chains, the presence of solar PV manufacturing in the United States does not imply a high level of U.S. content. Estimates dating to 2010, before the imposition of dumping and countervailing duties on imports from China, indicated that U.S. content accounted for 20% of the value of U.S.-installed crystalline silicon modules and 71% of the value of U.S.-installed thin-film modules. The level of U.S.-sourced content was estimated to be significantly higher for inverters (45% in 2010), mounting structures (94% in 2010), and combiner boxes and miscellaneous electrical equipment (59% in 2010).[54]

U.S. Solar Manufacturing Employment

As shown in **Figure 4**, the solar manufacturing sector supported 32,490 jobs nationwide in 2014, according to SEIA. This accounted for only about one-fifth of U.S. employment related to the solar energy sector.[55] The remaining 80% of the 141,317 full-time workers employed directly in the solar power industry as of November 2014 are involved in other segments of the industry including installation, sales and distribution, project development, research and development, and finance. U.S. government data indicate that employment in PV manufacturing may be much lower than the SEIA figures suggest. According to EIA, the number of full-time equivalent employees in the U.S. photovoltaic industry was 12,575 in 2012.[56]

[52] Stion, "Stion to Immediately Accelerate 2nd Half 2014 and 2015 Solar Panel Manufacturing Capacity," press release, June 11, 2014, http://www.stion.com/stion-to-immediately-accelerate-2nd-half-2014-and-2015-solar-panel-manufacturing-capacity/.

[53] Suniva, "Suniva Begins Construction on Second Solar Facility," press release, August 12, 2014, http://www.suniva.com/documents/Suniva%20Begins%20Construction%20on%20Second%20Solar%20Facility%202014%2008%2012.pdf.

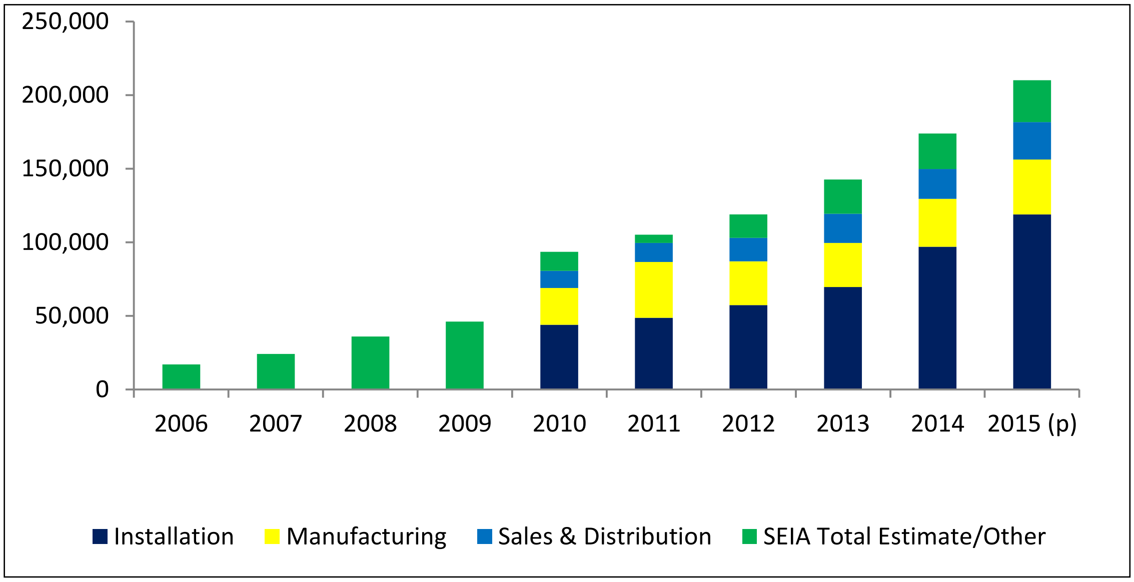
[54] SEIA, *U.S. Solar Energy Trade Assessment 2011*, August 2011, p. 45, see Figure 2-24.

[55] The Bureau of Labor Statistics (BLS) does not track employment data for the solar power industry, so the most authoritative data on solar jobs appear to be those in the National Solar Job Census Report, which can be accessed at http://www.solarfoundation.org. The count reported in that census includes jobs not related to PV, such as manufacturing of solar water heating systems.

[56] See U.S. EIA, *Solar Photovoltaic Cell/Module Shipments Report*, 2012, December 2013, Table 1, p. 7, http://www.eia.gov/renewable/annual/solar_photo/.

Figure 4. Domestic Solar Industry Employment Trends

(2006-2015)



Source: SEIA, National Solar Job Census, 2014; 2015 data are preliminary.

Notes: Other refers to project development, R&D, and finance. From 2006 to 2009, SEIA estimated the number of jobs and did not conduct a census for those years.

The number of solar manufacturing jobs has been relatively flat since 2012, even as total employment in the solar energy industry increased, according to figures from SEIA.[57] This is not surprising, as the majority of PV cells and modules are made overseas, including many that are manufactured by U.S. companies at offshore facilities. Domestic producers or assemblers of PV cells and modules do not employ a large number of workers. For example, SolarWorld had fewer than 1,000 production workers in 2013, and Suniva expects to employ a few hundred production workers when its newest factory in Michigan becomes fully operational. First Solar reportedly has more than 1,000 workers at its factory in Ohio.[58] These estimates, combined with the number of solar cell and module manufactures that have shuttered their operations in recent years, suggest that the near-term prospects for increased employment in solar manufacturing seem limited.

Solar manufacturing was responsible for a tiny sliver of the more than 12 million domestic manufacturing jobs in 2014. Even if there is a substantial increase in U.S. solar manufacturing capacity, solar PV manufacturing seems unlikely to become a major source of jobs. Employment growth is likely to depend not only upon future demand for solar energy, but also on corporate decisions about where to produce solar PV systems and components.

[57] The Solar Foundation, *National Solar Jobs Census 2014*, January 2015, p. 6. The Solar Foundation collects information on solar industry employment by surveying a "known universe" of firms in various segments of the industry, including construction, manufacturing, and sales and distribution, to fill the gap in government data. The Solar Foundation states that its national job census should be viewed as conservative, and that there may be more solar workers in the United States than reported in the annual survey.

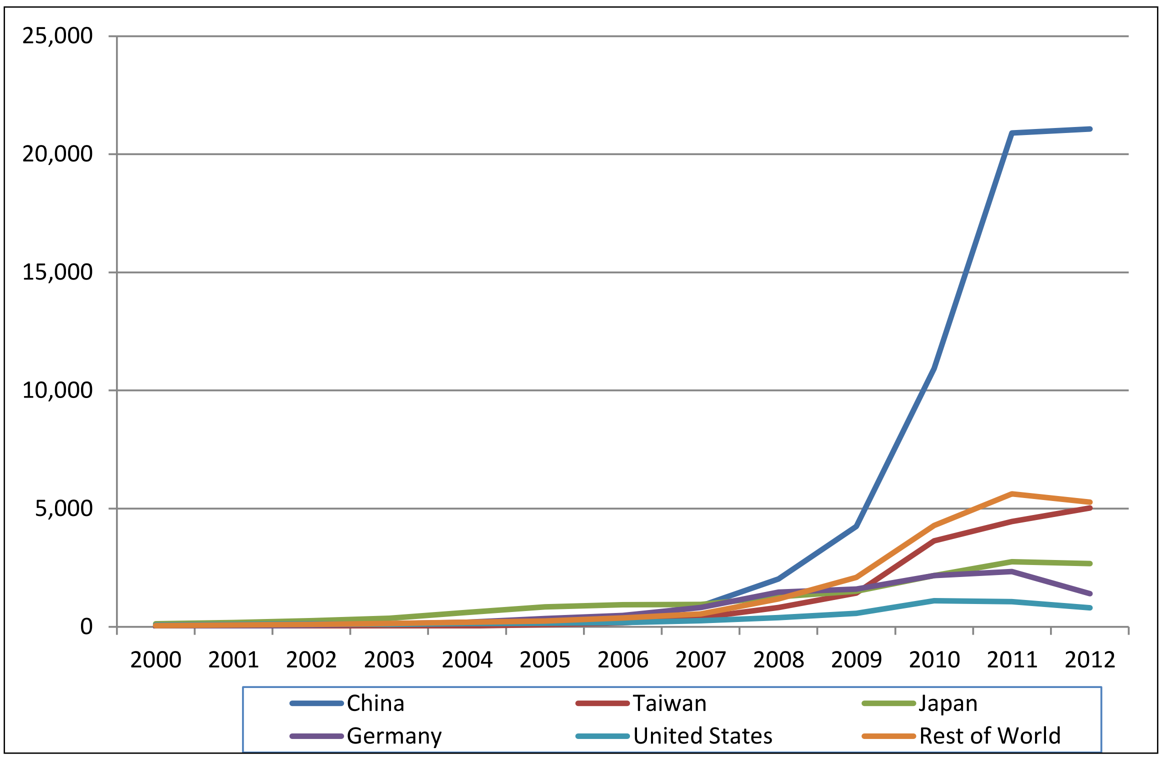
[58] James Ayre, *First Solar Increasing Manufacturing Staff at Ohio Fabrication Facility*, CleanTechnica, November 22, 2014, http://cleantechnica.com/2014/11/22/first-solar-increasing-manufacturing-staff-ohio-fabrication-facility/.

Global Production Shifts

The creation of incentives for solar installations in several countries around 2004 led many companies to enter the PV industry. More recently, the industry has entered a phase of rapid consolidation on a global basis. According to an estimate by SEIA, the number of module manufacturing facilities in the United States shrank from 51 in 2011 to 38 in 2013. Chinese cell production has been relatively flat because demand in some countries has declined and prices have weakened (see **Figure 5**). According to the International Energy Agency, there are now fewer than 100 Chinese PV module and cell manufacturers, compared with more than 300 companies in 2011.[59] By the end of 2017, China aims to reduce the number to 10 major producers that would supply 70%-80% of domestic demand.[60] Price pressures have driven a number of manufacturers, including the U.S. firms Evergreen Solar and Solyndra and the German companies Solon and Q-Cells, into bankruptcy, and have led others to lay off workers.

Figure 5. Annual Solar Cell Production by Country

(in Megawatts, 2000-2012)



Source: Data compiled by the Earth Policy Institute from GTM Research, http://www.earth-policy.org/data_center/C26.

[59] IEA-PV, *2013 PVPS Annual Report*, June 5, 2014, p. 47, http://www.iea-pvps.org/index.php?id=6.

[60] David Feldman, Robert Margolis, and Daniel Boff, *Q3/Q4 '14 Solar Industry Update*, U.S. Department of Energy, January 20, 2015, p. 7.

According to IEA-PVPS, China produced approximately two-thirds of the world's solar modules in 2013, and it ships the lion's share of all the PV modules that it produces to markets worldwide. In 2013, China's exports of modules totaled about 16.7 GW, worth about $10 billion.[61] Its domestic market for solar PV installations was small, at 19 GW in total installed PV capacity in 2013, but an increase from less than 1 GW in 2010. Driving this growth are policies to expand domestic solar PV demand, including direct grants for solar PV installations.[62] More recently, China implemented a nationwide feed-in tariff.[63] India aims to boost its domestic solar market to 20 GW of grid-connected electricity by 2022 using government programs like its National Solar Mission.[64]

Ten firms now control nearly half of global solar module production. Of these, six are based in China, two in Japan, one in South Korea, and one in the United States (see **Table 3**).

[61] Lv Fang, Xu Honghua, and Wang Sicheng, *National Survey Report of PV Power Applications in China*, IEA-PVPS, 2013, pp. 11-16.

[62] For a comparison of green energy programs and policies in China and the United States, see CRS Report R41748, *China and the United States—A Comparison of Green Energy Programs and Policies*, by Richard J. Campbell.

[63] Lv Fang, Xu Honghua, and Wang Sicheng, *National Survey Report of PV Power Applications in China*, IEA-PVPS, 2013, pp. 11-16.

[64] PV installations in India totaled about 1.1 GW in 2013 from having virtually no solar in 2009. IEA-PVPS, *Trends 2014 in Photovoltaic Applications*, October 10, 2014, p. 21.

Table 3. Top PV Solar Module Manufacturers by Production

(2013)

Rank	Manufacturer	Location of Headquarters	% of Module Production	Founded	Plant Locations (current and planned)
1	Yingli[a]	China	8.3%	1998	China
2	Trina Solar	China	6.7%	1997	China
3	Sharp[b]	Japan	5.4%	1959	Japan
4	Canadian Solar[c]	China	4.9%	2001	China
5	Jinko Solar	China	4.6%	2006	China
6	Renesola	China	4.5%	2005	China
7	First Solar[d]	United States	4.2%	1990	United States, Malaysia
8	Hanwha SolarOne[e]	South Korea	3.3%	2004	China, Malaysia, Germany
9	JA Solar	China	3.2%	2005	China
10	Kyocera	Japan	3.1%	1996	Japan, China, Czech Republic, Mexico

Source: Bloomberg New Energy Finance, "PV Production 2013: An all-Asian Affair," Solar Insight—Research Note, pp. 5-7, April 16, 2014.

a. Yingli Green Energy went public on June 8, 2007.

b. Sharp closed its factories in the United States and Europe.

c. Canadian Solar, incorporated in Canada, manufactures most of its solar modules in China.

d. First Solar closed its manufacturing operations in Germany in December 2012. It has also idled some of its production lines in Malaysia, cutting its global workforce by about 2,000 positions. See First Solar April 17, 2012, press release, "First Solar Restructures Operations to Align with Sustainable Market Opportunities," for more information, http://investor.firstsolar.com/releasedetail.cfm?ReleaseID=664717.

e. The Hanwha Group acquired the bankrupted German company Q Cells in 2012 and merged operations at the end of 2014. See "Hanwha SolarOne and Q Cells Announce Merger to Create New Solar Power Leader," December 8, 2014, http://investors.hanwha-solarone.com/releasedetail.cfm?ReleaseID=886464.

U.S. Trade in Solar Products

As part of their global business strategies, U.S. solar panel manufacturers source a significant share of components outside the United States. Imports of solar cells and panels nearly tripled from 2009, reaching $3.6 billion in 2013. Since 2009, imports of solar equipment rose every year, except for 2013, when PV imports shrank 29% from a year earlier (see **Table 4**).[65] The import decline may be related to the imposition of U.S. antidumping and countervailing duties on Chinese-manufactured solar cells in 2012, which resulted in double- and triple-digit tariffs on imports of PV products from China.

[65] The primary harmonized tariff schedule codes covering crystalline silicon PV cells, modules, or panels are HTS 8541.40.60.30 (cells) and HTS (8541.40.60.20 (modules), with a few import shipments also falling under HTS 8501.60.00.00 and 8507.20.80.

Most solar cells and modules imported into the United States come from Asia (see **Table 4**). Mexico is a relatively small exporter of PV modules to the United States, and its exports have been declining as manufacturers have closed some Mexican plants. Although U.S. imports of PV products from South Korea rose through 2012, South Korean manufacturers such as Hyundai Heavy Industry, LG Solar, and Samsung are reevaluating their business plans for the solar PV sector, contributing to a sharp drop in exports to the United States in 2013.[66] South Korea's stated goal of capturing 10% of the global PV market by 2020 may no longer be realistic.

Table 4. U.S. Imports of Solar Cells and Modules, Selected Countries

(in millions of U.S. dollars, 2009-2013)

	2009	2010	2011	2012	2013	% Change 2009-2013	% Change 2012-2013
Malaysia	$55	$139	$563	$1,470	$1,210	2,106%	-18%
China	$419	$1,192	$2,804	$1,686	$1,144	173%	-32%
Taiwan	$109	$264	$154	$408	$556	410%	36%
Mexico	$349	$481	$514	$482	$439	26%	-9%
Philippines	$172	$28	$242	$390	$97	-44%	-75%
World	$1,446	$2,645	$4,977	$5,103	$3,628	151%	-29%

Source: Global Trade Atlas. These statistics cover only solar cells and panels (HS 8541.40.6020 and HS 8541.40.6030).

International Trade Conflicts

Protracted trade cases involving solar equipment manufacturing have been initiated by the United States, China, the European Union, and India. The first case started in October 2011, when the Coalition for American Solar Manufacturing (CASM), led by the U.S. unit of SolarWorld, along with MX Solar USA, Helios Solar Works,[67] and four unnamed companies,[68] filed antidumping and countervailing duty petitions with the U.S. Department of Commerce (DOC) and the International Trade Commission (ITC). SolarWorld and CASM alleged that Chinese makers of crystalline silicon photovoltaic cells and modules had injured U.S. producers by selling their products in the United States at below-market prices, and that the Chinese government had provided illegal subsidies to these manufacturers.[69] The CASM petition asked DOC to levy tariffs

[66] Eileen Yu, "Korean Tech Giants not having Much Luck in Solar," *ZDNet*, April 7, 2014, http://www.zdnet.com/article/korean-tech-giants-not-having-much-luck-in-solar/.

[67] In 2013, Helios Solar Works filed for receivership (a process similar to bankruptcy) and closed its solar panel factory in Wisconsin. The company is now owned by Chinaland Solar Energy, which reportedly may open a solar panel plant in North Carolina.

[68] Four petitioners remained anonymous, fearing retaliation by China. CASM represents more than 250 members with around 22,000 employees. Other groups publicly supporting the trade action include the United Steelworkers. For more information, see the CASM website at http://www.americansolarmanufacturing.org.

[69] In the United States, there are two dispute-resolution systems specifically designed to handle company complaints about apparently anticompetitive trade practices: antidumping and countervailing duty mechanisms. The process for antidumping and countervailing duty cases such as the one initiated by CASM can be divided into five stages, each

of up to 250% on solar cells and modules imported from China. Upon finishing their respective investigations in late 2012, DOC[70] and the ITC[71] each ruled these products had been unfairly priced and subsidized. In the first case, the final antidumping duties on solar cells and modules imported from China ranged from 18.3% to 249.9%, with the majority of tariffs at 24.5%. Countervailing duties ranged from 14.78% to 15.97%.[72] U.S. Customs and Border Protection will collect these duties at least through October 31, 2017.[73] In December 2014, the World Trade Organization (WTO) appellate body said that U.S. countervailing duties on Chinese solar panels breached global trade rules.[74]

After the United States imposed tariffs on Chinese PV producers, the Chinese government brought its own antidumping and countervailing duty cases against polysilicon imported into China from the United States and South Korea. In January 2014, the Chinese government responded by issuing final antidumping rates on U.S. polysilicon producers, which included antidumping margins of 57% for REC Silicon, 53.3% for Hemlock Semiconductor, and 53.7% for MEMC (now known as SunEdison).[75] China followed up with countervailing duties on U.S. polysilicon of up to 6.5%.[76] The tariffs do not apply to imports into China from the United States of silicon used in the production of exported modules, which allows U.S. firms to continue to supply polysilicon to Chinese ingot and wafer manufacturers.

SolarWorld and CASM responded positively to the duties levied by the United States against China in the 2011-2012 investigation.[77] Still, SolarWorld and some Members of Congress

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ending with a finding by either DOC or the ITC. These stages with the deadlines governed by statute are as follows: (1) initiation of the investigation by the DOC (20 days after filing the petition); (2) the preliminary phase of the ITC's investigation into whether U.S. producers have been injured (with a preliminary determination within 45 days after filing of the petition); (3) the preliminary phase of the DOC investigation (with a preliminary determination within 190 days after the ITC's determination for antidumping cases or within 130 days for countervailing duty cases); (4) the final phase of the DOC investigation (with a final determination within 75 days for a CVD case and within 135 days in AD cases); and (5) the final phase of the ITC's investigation (with a final determination within 45-75 days). CRS Report IF10018, *Trade Remedies: Antidumping and Countervailing Duties*, by Vivian C. Jones, gives an overview of the antidumping and countervailing duty process.

[70] International Trade Administration (ITA), *Fact Sheet*, Commerce Finds Dumping and Subsidization of Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled into Modules from the People's Republic of China, October 10, 2012, http://enforcement.trade.gov/download/factsheets/factsheet_prc-solar-cells-ad-cvd-finals-20121010.pdf.

[71] USITC, "Crystalline Silicon Photovoltaic Cells and Modules from China Injure U.S. Industry, Says USITC," press release, November 7, 2012, http://www.usitc.gov/press_room/news_release/2012/er1107kk1.htm.

[72] For a list of tariffs by company, exporter, or producer, see Department of Commerce (DOC), "Crystalline Silicon Photovoltaic Cells," 77 *Federal Register* 73018-73021, December 7, 2012, http://www.gpo.gov/fdsys/pkg/FR-2012-12-07/pdf/2012-29668.pdf.

[73] After issuing an antidumping (AD) or countervailing duty (CVD) order, if requested by an interested party, DOC may conduct annual administrative reviews of AD or CVD orders, during the anniversary month of an order. The outcome of a review may raise or lower the actual AD or CVD assessments for the period of review. After five years, the department initiates a sunset review to determine whether to continue or revoke the order.

[74] World Trade Organization (WTO), *United States—Countervailing Duty Measures on Certain Products from China*, AB-2014-8, December 18, 2014, http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds437_e.htm#bkmk437abr.

[75] The China Ministry of Commerce (MOFCOM) assessed lower tariffs on South Korea's polysilicon producers, ranging from 2.4% to 48.7%. See "MOFCOM Announcement No. 48 of 2013 on the Preliminary Ruling of the Anti-Dumping Against Imports of Solar-Grade Polysilicon Originated in the USA and South Korea," http://insidetrade.com/iwpfile.html?file=jul2013%2Fwto2013_2316c.pdf and http://insidetrade.com/iwpfile.html?file=jan2014%2Fwto2014_0171b.pdf.

[76] MOFCOM, "MOFCOM Announcement No. 63 of 2013 on the Preliminary Ruling of the Countervailing Investigation Against Imports of Solar-Garde Polysilicon Originated in the United States," press release, September 16, 2013, http://insidetrade.com/iwpfile.html?file=sep2013%2Fwto2013_2877c.pdf.

[77] SolarWorld, "SolarWorld Applauds Trade Panel for Vote to Counter Illegal Chinese Trade Practices," press release,

objected to its scope, which they claimed should have been extended to solar modules made in China that incorporate solar components from other countries such as Taiwan.[78] SolarWorld argued that the "loophole" resulted in Chinese manufacturers avoiding the punitive duties by using slightly more expensive Taiwan-manufactured solar cells to make U.S.-bound solar modules in China.[79] In 2014, SolarWorld, with the continued support of CASM, filed new antidumping and countervailing duty cases with the ITC and DOC.[80] Unlike the 2012 petitions, the 2014 cases included both PV cells and modules made in China, and the antidumping investigation extended to PV cells and modules made in Taiwan. In a final decision in December 2014, DOC announced antidumping margins ranging from 26.71% to 165% for Chinese exporters, and countervailing duties from 27.64% to 49.79%. For Taiwanese companies, the antidumping duties range from 11.45% to 27.55%.[81] The ITC confirmed DOC's final decision, setting an effective date for the new antidumping and countervailing of February 5, 2015.[82]

SEIA[83] and the Coalition for Affordable Solar Energy (CASE)[84] strongly opposed the second SolarWorld/CASM petition. They claim higher tariffs on PV imports from China would curb domestic demand for solar products by substantially increasing costs in major segments of the U.S. solar industry. In addition, they argue the tariffs erode profit margins across the PV value chain. CASE attributes any injury to the U.S. industry on polysilicon pricing, thin-film panel competition, and the loss of U.S. government incentives. In 2013, SEIA proposed a negotiated solution to avoid further escalation of the solar trade frictions between the United States and China.[85] The SEIA proposal would require China to revoke its tariffs on solar imports by China, that the United States remove its duties for at least five years, and that Chinese manufacturers pay into a U.S. Solar Manufacturing Settlement Fund to support U.S. manufacturers.[86]

November 7, 2012, http://www.solarworld-usa.com/newsroom/news-releases/news/2012/solarworld-applauds-trade-panel-vote.

[78] Eight Members of Congress, including Senators Ron Wyden and Sherrod Brown, wrote to Rebecca Blank, then Acting Secretary of Commerce, on September 27, 2012, urging DOC to expand the investigation to include modules containing cells manufactured in countries outside of China. To view the letter, see http://www.wyden.senate.gov/download/?id=283b6c18-c246-4b23-a576-4b846809e682&download=1.

[79] Wiley Rein LLP, *Certain Crystalline Silicon Photovoltaic Products from China and Taiwan*, Inv. Nos. 701-TA-511 and 731-TA-1246-1247 (Final) Hearing, December 8, 2014, p. 7.

[80] ITA, "Certain Crystalline Silicon Photovoltaic Products from the People's Republic of China and Taiwan: Initiation of Antidumping Duty Investigations," 79 *Federal Register* 4661-4667, January 29, 2014.

[81] This is the first antidumping case against Taiwan covering PV cells. Products from China captured by the scope of the 2012 antidumping order are not subject to new duties. See DOC Fact Sheet, "Commerce Finds Dumping of Imports of Certain Crystalline Silicon Photovoltaic Products from China and Taiwan and Countervailable Subsidization of Imports of Certain Crystalline Silicon Photovoltaic Products from China," December 16, 2014, http://enforcement.trade.gov/download/factsheets/factsheet-multiple-certain-crystalline-silicon-photovoltaic-products-ad-cvd-final-121614.pdf.

[82] USITC, "Certain Crystalline Silicon Photovoltaic Products from China and Taiwan," press release, January 21, 2015, http://www.usitc.gov/press_room/news_release/2015/er0121ll329.htm.

[83] SEIA, "U.S.-China Trade Ruling Poses Threat to Solar Industry's Growth," press release, December 16, 2014, http://www.seia.org/news/us-china-trade-ruling-poses-threat-solar-industrys-growth.

[84] CASE, "CASE Calls International Trade Commission Vote Disappointing," press release, January 21, 2015, http://affordablesolarusa.org/wp-content/uploads/2015/01/CASE-Release-ITC-final.pdf. CASE claims to represent about 200 solar installation firms, retailers, and system owners, and solar panel manufacturers owned or operating in the United States. For a list of CASE members, see http://affordablesolarusa.org/case-members/.

[85] SEIA, *Draft Recommendation to Governments for the Establishment of a U.S.-China Solar Agreement*, August 14, 2013, http://www.seia.org//research-resources/draft-recommendation-governments-establishment-us-china-solar-agreement.

[86] SEIA, "SEIA Continues to Push for Negotiated Trade Solution," press release, January 21, 2015,

Solar equipment disputes have expanded beyond the United States and China. For example, the European Commission brought trade cases against solar products from China, which, in August 2013, resulted in a government-to-government agreement limiting imports and setting a floor price on China's solar exports to the European Union.[87] In another case, the United States filed a WTO action against India because of its domestic content requirements, which the United States claims discriminate against U.S. solar cells and modules.[88]

U.S. Exports

U.S. PV exports to the world remain small, at slightly more than $350 million in 2013, shrinking from a high of $1.4 billion in 2010. In 2013, Japan and Germany were the two largest foreign markets for U.S. solar PV exports, at $162 million and $44 million, respectively. PV cell and module exports from the United States to China were valued at $14.4 million in 2013. A DOC analysis predicts that in 2015, Canada and Chile will account for more than half of all U.S. exports of solar products.[89]

U.S. exporters of solar cells and panels generally do not face foreign tariffs because of the Information Technology Agreement, whose signatories have agreed to eliminate duties on information technology products.[90] Tariffs in other parts of the PV value chain are also comparably low. For example, the applied tariff on silicon is between zero and 4% in the leading cell- and module-producing countries.[91] However, non-tariff barriers can be significant, including local content requirements at the national level or sub-national level in places like India, Canada, South Africa, and Saudi Arabia and other policies that encourage the use of local content in countries like Italy.

Besides these mandates, import charges and taxes, customs procedures, and divergent product standards can hinder trade in solar PV components in markets such as Korea and Japan.[92] Subsidies for domestic production in major overseas markets like China are another potential constraint on U.S. exports.[93] Talks on environmental goods launched in June 2014 among 14 WTO countries, including the United States and China, seek to address non-tariff barriers,

http://www.seia.org/news/seia-continues-push-negotiated-trade-solution.

[87] European Commission, "European Commission Adopts Price Undertaking in EU-China Solar Panels Case," press release, August 2, 2013, http://trade.ec.europa.eu/doclib/press/index.cfm?id=957.

[88] WTO, *India—Certain Measures Relating to Solar Cells and Solar Modules*, Dispute DS456, http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds456_e.htm.

[89] U.S. Department of Commerce—International Trade Administration, *Renewable Energy Top Markets for U.S. Exports 2014-2015*, A Market Assessment Tool for U.S. Exporters, February 2014, p. 58, http://export.gov/build/groups/public/@eg_main/@reee/documents/webcontent/eg_main_070688.pdf.

[90] Generally, solar cells and modules enter foreign markets under the harmonized tariff schedule (HTS) 8541.40.60.20 and 8541.40.60.30, which are included in the Information Technology Agreement. The EU, Canada, Japan, India, Malaysia, and China are among its signatories. Absent are some large countries such as Brazil, which charges a 12% duty rate on most imported solar equipment, both PV and thermal. Background on the Information Technology Agreement can be found on the WTO website at http://www.wto.org/english/tratop_E/inftec_e/inftec_e.htm.

[91] Silicon enters foreign markets under HTS 2804.61. The EU's applied tariff is zero, China's is 4%, Malaysia's is zero, and the Philippines' is 3%. South Korea's applied tariff is 3% for non-FTA member countries, but because of the U.S.-Korea Free Trade Agreement, the duty rate for silicon exports from the United States to South Korea is zero.

[92] U.S. Department of Commerce, International Trade Administration, *Renewable Energy Top Markets for U.S. Exports 2014-2015*, A Market Assessment Tool for U.S. Exporters, February 2014, p. 58, http://export.gov/build/groups/public/@eg_main/@reee/documents/webcontent/eg_main_070688.pdf.

[93] For more information on renewable energy policies by country, see *Renewables 2014 Global Status Report*, Ren 21, pp. 76-83, http://www.ren21.net/portals/0/documents/resources/gsr/2014/gsr2014_full%20report_low%20res.pdf.

including trade remedies, which impose higher trade costs.[94] Several U.S. government programs encourage the export of renewable energy products. Targeting large emerging markets like India, the Export-Import Bank provides direct loans to solar manufacturers through its Environmental Products Program, under which it allocates a certain portion of funding to renewable energy and energy-efficient technologies. Recent Ex-Im Bank beneficiaries in the solar sector include MiaSole, which received a $9 million direct loan to support the export of solar modules to India,[95] SolarWorld, which received a $6.4 million guarantee to finance the export of solar modules to Barbados,[96] and Suniva, which got a $780,000 loan guarantee for solar module exports to Mexico.[97]

U.S. Government Support for Solar Power

Federal policies favoring development of a domestic solar power sector include support for the U.S. solar PV manufacturing industry as well as incentives for solar generation of electricity. Three of the five programs listed below have expired.

- An advanced energy manufacturing tax credit (MTC) was aimed at supporting renewable energy manufacturers. It reached its funding cap in 2010.
- The Section 1705 Loan Guarantee Program directed funds to manufacturing facilities that employ "new or significantly improved" technologies. The program expired in 2011.
- The investment tax credit (ITC) provides financial incentives for solar power at a rate of 30%. Without legislative action, the ITC is due to end on December 31, 2016, after which it will revert to a permanent rate of 10% for commercial investments and expire for residential investments.
- The Section 1603 Treasury Cash Grant Program requires solar projects to have commenced construction by December 31, 2011, and to complete construction by December 31, 2016.
- The Sunshot Initiative is one of several DOE programs to support the solar industry and increase domestic PV manufacturing.

[94] USTR, "Fact Sheet: WTO Environmental Goods Agreement: Promoting Made-In-America Clean Technology Exports, Green Growth and Jobs," press release, July 8, 2014, http://www.ustr.gov/about-us/press-office/fact-sheets/2014/July/WTO-EGA-Promoting-Made-in-America-Clean-Technology-Exports-Green-Growth-Jobs.

[95] Export-Import Bank of the United States, "California Company MiaSole Exports Thin-Film Solar Panels for Solar-Energy Project in India, Backed by $9 Million Ex-Im Bank Loan," press release, March 26, 2013, http://www.exim.gov/newsandevents/releases/2013/California-Company-Miasole-Exports-Thin-Film-Solar-Panels-for-Solar-Energy-Project-in-India-Backed-by-9-Million-ExIm-Bank-Loan.cfm. The Chinese electricity producer Hanergy acquired MiaSole in 2012.

[96] Export-Import Bank of the United States, "Ex-Im Guarantees PNC Loan to Finance Solar Power in Barbados; Supports Small Business Jobs in Five States," press release, September 28, 2012, http://www.exim.gov/newsandevents/releases/2012/exim-guarantees-pnc-loan-to-finance-solar-power-in-barbados-supports-small-business-jobs-in-five-states.cfm/.

[97] Export-Import Bank of the United States, "Ex-Im Approves $780,000 Loan Guarantee to Finance U.S. Solar-Module Exports to Mexican Rooftop Solar-Power Project Projects in India," press release, January 28, 2013, http://www.exim.gov/newsandevents/releases/2013/ExIm-Bank-Approves-780000-Loan-Guarantee-To-Finance-US-SolarModule-Exports-to-Mexican-Rooftop-SolarPower-Project.cfm.

Advanced Energy Manufacturing Tax Credit

The Advanced Energy Manufacturing Tax Credit, Section 48C, which was included in the American Recovery and Reinvestment Act of 2009,[98] provided a 30% tax credit to advanced energy manufacturers that invested in new, expanded, or reequipped manufacturing facilities built in the United States. Solar panel manufacturing was among the 183 projects funded through the MTC before it reached its cap of $2.3 billion in 2010.[99] Plants receiving the credit had until February 17, 2013, to begin operations. Solar PV manufacturers benefiting from the credit included Abound Solar, Calisolar, MiaSole, First Solar, Sharp, Suniva, Suntech, and Yingli. At least three PV manufacturers that received tax credits under the 48C program—Xunlight, Abound, and Sharp—have closed their factories.[100] Despite the Obama Administration's request for another $5 billion for the 48C credit, Congress has not allocated additional money for the program.[101]

DOE Loan Guarantee Programs

The Section 1705 loan guarantee program was a temporary program established under the American Reinvestment and Recovery Act (P.L. 111-5) to provide loan guarantees for renewable energy projects including solar manufacturing and solar power generation projects. A Congressional Research Service report found that solar projects accounted for more than 80% of the of the Section 1705 loan guarantees, totaling $13.27 billion.[102] The loan guarantee program included 16 solar projects, of which four were manufacturing projects. Of the four manufacturers, Solyndra declared bankruptcy in late 2011 and defaulted on its $535 million loan, Abound Solar received about $70 million of its $400 million loan before shuttering its solar panel operation and filing for bankruptcy in 2012, and SoloPower never met the requirements to initiate its $197 million loan guarantee.[103] 1366 Technologies, which received a $150 million guarantee, is the only participant still actively manufacturing solar PV equipment.[104] The Section 1705 loan program expired on September 30, 2011.

[98] The credit was authorized in Section 1302 of the American Recovery and Reinvestment Act.

[99] White House, "President Obama Awards $2.3 Billion for New Clean-Tech Manufacturing Jobs," press release, January 8, 2010, http://www.whitehouse.gov/the-press-office/president-obama-awards-23-billion-new-clean-tech-manufacturing-jobs.

[100] A full list of the projects selected for the tax credit is available at http://www.whitehouse.gov/the-press-office/president-obama-awards-23-billion-new-clean-tech-manufacturing-jobs.

[101] Twenty-eight Democratic senators sent a letter to Senators Ron Wyden and Orrin Hatch on tax programs for renewable energy sectors, March 26, 2014, http://www.markey.senate.gov/imo/media/doc/2014-3-26_Clean_Energy_Tax_Credits.pdf.

[102] The remaining 18% supported a variety of projects in other renewable energy sectors including biofuels, energy storage, wind generation, transmission, and geothermal electricity. See CRS Report R42059, *Solar Projects: DOE Section 1705 Loan Guarantees*, by Phillip Brown.

[103] In 2013, SoloPower closed its factory in Oregon, and DOE pulled the company's 1705 loan guarantee funding. SoloPower changed its name to SoloPower Systems Inc. in summer 2013, and it announced plans in 2014 to restart its manufacturing operations.

[104] See Martin La Monica, "1366 Technologies," *MIT Review*, February 18, 2014; and Molly Young, "As SoloPower System Misses Latest Payment Deadline, State not Ready to Foreclose," *Oregonian*, April 8, 2014.

Investment Tax Credit (ITC)

The Investment Tax Credit for solar was first adopted as part of the Energy Tax Act of 1978,[105] and has been continuously available since that time (when there have been lapses, the credit has been retroactively extended). The current ITC, allowing residential and commercial owners of solar projects to offset 30% of a solar system's cost through tax credits, is in place through the end of 2016,[106] when it is scheduled to revert back to a permanent rate of 10% for commercial investments and lapse entirely for residential investments.[107] In practice, developers of utility-scale solar projects often do not have sufficient income to benefit from the credit, so projects have been developed through structures that transfer the benefit to third-party "tax equity" investors.

In 2009, as part of ARRA, the ITC was modified and a new program was adopted which provided a new tax option for solar power developers: a direct cash grant, which may be taken in lieu of the federal business energy investment tax credit that they were otherwise entitled to receive. In the 113th Congress, the Renewable Energy Parity Act of 2014 (S. 2003) was introduced by Senators Michael Bennet and Dean Heller to make firms eligible for tax credits for projects that are already under construction before the credit's expiration date, instead of having to wait until those projects are competed and in service. More than two dozen Members of Congress have voiced their support for modifying the construction qualification to the solar investment tax credit to ensure that solar projects underway will come to fruition.[108] Other Members argue for letting the credit drop to 10% in 2017 as planned because the solar industry no longer needs such incentives. It is uncertain what impact a reduction in the credit will have on solar installations across the United States.

1603 Cash Grant Program

The Section 1603 Treasury Grant program expired at the end of 2011. It allowed owners of renewable energy systems to apply for cash grants to cover 30% of the systems' cost, regardless of their tax liability. Through October 15, 2014, the 1603 Treasury Program had awarded grants to more than 95,000 individual solar projects totaling $7.3 billion.[109] While an ITC, which reduces overall tax liability, will still be available for solar projects until 2016, it is viewed as a less favorable incentive than the cash grant.

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[105] P.L. 95-618.

[106] The current ITC rate of 30% was first introduced as part of the Energy Policy Act of 2005 (P.L. 109-58), and the eight-year extension of the commercial and residential solar ITC was part of the Emergency Economic Stabilization Act of 2008 (P.L. 110-343).

[107] The permanent 10% rate for solar was part of the Energy Policy Act of 1992 (P.L. 102-486). The credit rate fluctuated between 10% and 15% between 1980 and 1992, as it was changed by numerous pieces of legislation during this time.

[108] On March 11, 2014, 26 Senators sent a letter to Senate Majority Leader Harry Reid and Senate Committee on Finance Chairman Ron Wyden in support of modifying the eligibility standard under the Section 48 Investment Tax Credit. A copy of this letter can be found at http://www.seia.org/sites/default/files/resources/14%2003%2011%20SL%20ITC%20Commence%20Construction.pdf#overlay-context=research-resources/key-developments.

[109] U.S. Department of Treasury, *Overview and Status Update of the 1603 Program*, October 15, 2014, p. 2, http://www.treasury.gov/initiatives/recovery/Documents/P%20Status%20overview%202014-10-15.pdf.

SunShot and Other DOE Initiatives

The U.S. Department of Energy, which has set a goal for solar energy to provide 14% of domestic electricity by 2030 and 27% by 2050, runs a number of efforts intended to create a stronger domestic PV manufacturing base, under the SunShot Initiative.[110] These include

- the PV incubator program, which began in 2007 and aims to support promising commercial manufacturing processes and products;[111]
- the PV supply chain and cross-cutting technologies project, which provides up to $20.3 million in funds to non-solar companies that may have technologies and practices that could strengthen the domestic PV industry;[112]
- the Advanced Solar Photovoltaic Manufacturing Initiative (PVMI), with up to $112.5 million in funding over five years, to advance manufacturing techniques to lower the cost of producing PV panels;[113] and
- SUNPATH, which stands for Scaling Up Nascent PV At Home and is funded at less than $45 million, aims to increase domestic manufacturing by supporting industrial-scale demonstration projects for PV modules, cells, substrates, or module components.[114]

A separate DOE program to strengthen PV manufacturing is the Advanced Research Project Agency-Energy program, or ARPA-E, which received $280 million in FY2014. ARPA-E funds transformative energy research that is not being supported by other parts of DOE or the private sector because of technical and financial uncertainty. As of August 2013, ARPA-E has funded 285 projects.[115] 1366 Technologies, a silicon PV company, and Applied Materials, a semiconductor production equipment manufacturer, are among the solar manufacturers to receive federal funding through this program.[116]

Conclusions

Solar manufacturing continues to go through a shakeout, with manufacturers closing U.S. plants because of difficult global business conditions, stiff competition particularly from Chinese companies, and falling prices for solar panels. Beyond that, the extraction of large quantities of shale gas seems likely to lower the cost of generating electricity from natural gas, potentially reducing demand for solar panels.[117] While state-level renewable fuels standards, which require utilities to obtain a certain proportion of their electricity from renewable sources, may provide

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[110] U.S. Department of Energy, *SunShot Vision Study*, February 2012, http://www1.eere.energy.gov/solar/pdfs/47927.pdf.

[111] According to DOE, the Sunshot Incubator Program has given 61 startup companies at total of 74 awards since 2007. For more information, see U.S. Department of Energy, *Photovoltaic Technology Incubator*, http://www1.eere.energy.gov/solar/pv_incubator.html.

[112] U.S. Department of Energy, *Photovoltaic Supply Chain and Cross-Cutting Technologies*, http://www1.eere.energy.gov/solar/sunshot/pv_supply_chain.html.

[113] For more information on these programs, see DOE, SunShot Photovoltaic Manufacturing Initiative, http://www1.eere.energy.gov/solar/sunshot/pvmi.html.

[114] EERE, *Notice of Intent to Issue Funding Opportunity for Sunshot Incubator 10, SolarMat 3, and SunPath Round 2*, http://energy.gov/eere/sunshot/notice-intent-issue-funding-opportunity-sunshot-incubator-10-solarmat-3-and-sunpath-2.

[115] ARPA-E, Frequently Asked Questions, http://arpa-e.energy.gov/?q=faq.

[116] For ARPA-E projects and programs, see http://arpa-e.energy.gov/?q=arpa-e-site-page/projects.

[117] Leah Goddard, *Solar Panel Manufacturing in the US*, IBISWorld, Alternating Current: International Competition and Waning Demand Will Cripple Revenue, December 2014, p. 6.

continuing demand for utility-scale PV installations in some states, the lower cost of gas-fired generation may limit interest.

In some parts of the United States, residential and commercial PV systems produce electricity at prices competitive with conventional grid electricity, once subsidies are taken into account. However, although the per-watt cost of solar PV systems has declined significantly, in most areas of the country solar power is still not competitive with power generated from fossil fuels. The cost disadvantage could widen if subsidies are unavailable or if retail electricity prices decline due to the lower price of natural gas. In the absence of continued government support for solar installations or for the production of solar equipment, the prospects for expansion of domestic PV solar manufacturing may be limited.

Appendix. Historical Overview

Modern photovoltaic technology traces its roots back to 19th-century breakthroughs by scientists from Europe and the United States. In 1839, a French physicist, Alexandre Edmond Becquerel, discovered the photovoltaic effect,[118] and in 1883, an American inventor, Charles Fritts, made the first primitive solar cell.[119] Progress in modern solar cell manufacturing began in the 1940s and 1950s when Russell Ohl discovered that a rod of silicon with impurities created an electric voltage when illuminated and three scientists at Bell Laboratories in New Jersey (Daryl Chapin, Calvin Fuller, and Gerald Pearson) developed the first commercial photovoltaic cell.

Further advancing PV cell manufacturing was the space race of the 1960s, with the competition between the United States and the former Soviet Union driving demand for solar cells, which were, and still are, used to power some spacecraft and satellites.[120] The first generation of photovoltaic manufacturing firms included such names as Hoffman Electronics, Heliotek,[121] RCA, International Rectifier, and Texas Instruments. The technology, however, remained too expensive for other uses, and the market remained very small.[122] The Japanese manufacturer Sharp pioneered the use of photovoltaics on earth, using them to power hundreds of lighthouses along the Japanese coast, but it could not identify other applications for which photovoltaics were cost-competitive.

The oil crises of the 1970s hastened the development of modern solar panels by a second generation of PV firms, which focused on ground applications. Major oil and gas companies entered the field.[123] Exxon underwrote the Solar Power Corporation.[124] Atlantic Richfield Company (ARCO) purchased Solar Technology International and renamed it ARCO Solar in 1977; its corporate descendant is now part of SolarWorld, presently the largest cell manufacturer in the United States. First Solar, one of the biggest manufacturers of PV thin-film cells, can trace its roots to Toledo, OH, where it was established in 1984 as Glasstech Solar.

The first direct federal support for solar manufacturing was during the Carter Administration. The Energy Tax Act (ETA) of 1978[125] provided tax credits for homeowners who invested in solar and certain other technologies. Additionally, the federal government through the Public Utility

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118 The photovoltaic effect is the basic physical process through which a PV cell converts sunlight into electricity. Sunlight is composed of photons—packets of solar energy. These photons contain different amounts of energy that correspond to the different wavelengths of the solar spectrum. When photons strike a PV cell, they may be reflected or absorbed, or they may pass right through. The absorbed photons generate electricity.

119 Fritts made his first cell from selenium. The semiconductor had a thin coat of gold around it and was not very effective in generating electricity. The reason, now known, is that selenium is not a very good semiconductor.

120 In 1958, PV solar cells received considerable attention because they partially powered the Vanguard 1 satellite launched by the United States. PV cells power nearly all of today's satellites because they can operate for long periods with virtually no maintenance.

121 Heliotek merged with Spectrolab, and produces high-efficiency cells today.

122 Phech Colatat, Georgeta Vidican, and Richard K. Lester, *Innovation Systems in the Solar Photovoltaic Industry: The Role of Public Research Institutions*, Industrial Performance Center Massachusetts Institute of Technology, Cambridge, MA, June 2009, p. 4, http://web.mit.edu/ipc/research/energy/pdf/EIP_09-007.pdf.

123 Oil and gas companies used solar power to protect wellheads and underground pipelines from corrosion and to power navigational aids on offshore oil rigs.

124 Elliott Berman, who founded Solar Power Corporation, pioneered a number of manufacturing changes including buying cheap solar wafers that had been cast aside by the semiconductor industry, which helped to reduce the cost of solar cells, lowering the selling price from $100 per watt in 1970 to $20 per watt in 1973.

125 P.L. 95-618. ETA created residential solar credits of up to $2,000 for devices installed on homes. They were in effect from April 20, 1977 to January 1, 1986.

Regulatory Policies Act required utilities to purchase power produced by qualified renewable power facilities.[126]

Notwithstanding this support, production of solar PV power in the United States remained small. By the mid-1980s, domestic photovoltaic manufacturers were selling products at a loss, and many were struggling. President Reagan's Tax Reform Act of 1986 reduced the Investment Tax Credit (ITC) to 10% in 1988, where it remained until 2005. Because of these policy changes, combined with the sustained drop in petroleum prices, solar manufacturing slumped until 2005, when President George W. Bush signed the Energy Policy Act (EPAct).[127] That law included a 30% ITC for property owners who installed commercial and residential solar energy systems.[128]

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Disclaimer

[126] P.L. 95-617. For more information on the history of renewable energy policy see CRS Report RL33588, *Renewable Energy Policy: Tax Credit, Budget, and Regulatory Issues*, by Fred Sissine.

[127] P.L. 109-58.

[128] EPAct tax incentives for solar energy applied from January 1, 2006, through December 31, 2007, and the Tax Relief and Health Care Act of 2006 (P.L. 109-432) extended these credits for one additional year. For background on the Solar Investment Tax Credit see SEIA backgrounder, *The Case for the Solar Investment Tax Credit*, SEIA, http://www.seia.org/galleries/pdf/The_Case_for_the_Solar_Investment_Tax_Credit.pdf.